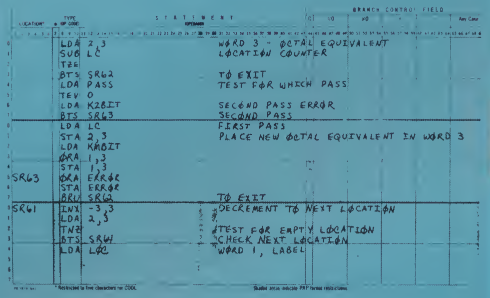
GEA-8021 A

$$A_X + B_Y + C_Z = K$$

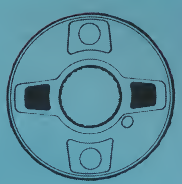
Σ Σ Σ Σ

```
01203   00000160   00076755          LDA WRD2
01204   21000101   21076675          ORA ERROR
01205   32000101   32076674          STA ERROR
01206   00500002   00500002          LDA 2,3
01207   31000104   31076675          SUB LC
01210   05004670   05004670          TZE
01211   34001245   34040034          BTS SR62
01212   00000102   00076670          LDA PASS
01213   05070700   05070700          TEV 0
01214   00001250   00077034          LDA K2BIT
01215   34001223   34040006          BTS SR63
01216   00000104   00076066          LDA LC
01217   32500002   32500002          STA 2,3
01220   00000242   00077022          LDA KMBIT
01221   21500001   21500001          ORA 1,3
01222   32500001   32500001          STA 1,3
01223   21000101   21076056   SR63   ORA ERROR
01224   32000101   32076655          STA ERROR
01225   14001245   14040020          BRU SR62
01226   26537775   26537775   SR61   INX -3,3
01227   00500002   00500002          LDA 2,3
01230   05004770   05004770          TNZ
01231   34001167   34077736          BTS SR64
01232   00000110   00076656   SR611  LDA LOC
```

$$F(X, Y) = (X + Y) * (X - Y)$$


```
        LDA 2,3          WØRD 3 - ØCTAL EQUIVALENT
        SUB LC           LØCATIØN CØUNTER
        TZE
        BTS SR62         TØ EXIT
        LDA PASS         TEST FØR WHICH PASS
        TEV 0
        LDA K2BIT        SECØND PASS ERRØR
        BTS SR63         SECØND PASS
        LDA LC           FIRST PASS
        STA 2,3          PLACE NEW ØCTAL EQUIVALENT IN WØRD 3
        LDA KMBIT
        ØRA 1,3
        STA 1,3
SR63    ØRA ERRØR
        STA ERRØR
        BRU SR62         TØ EXIT
SR61    INX -3,3         DECREMENT TØ NEXT LØCATIØN
        LDA 2,3
        TNZ              TEST FØR EMPTY LØCATIØN
        BTS SR61         CHECK NEXT LØCATIØN
        LDA LØC          WØRD 1, LABEL
```


$\int$



SOFTWARE

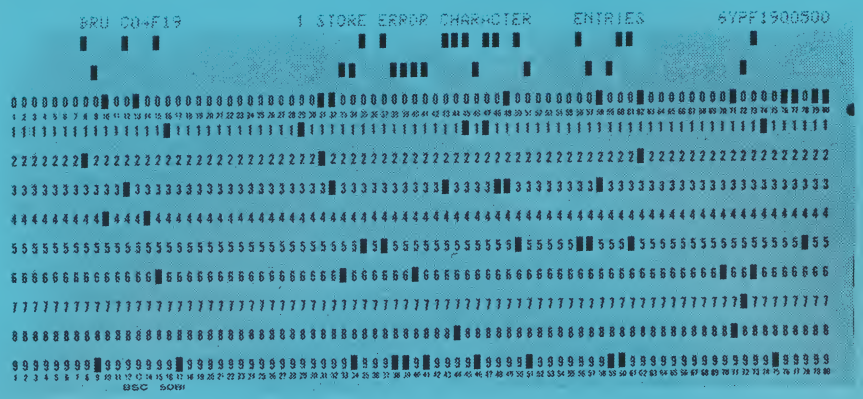
for the

GE PAC 4000

GENERAL ELECTRIC PROCESS AUTOMATION COMPUTER

GENERAL ELECTRIC

FEATURES



COMPUTER SOFTWARE is the intelligence of a computer system that tells the equipment what to do and when to do it. Software includes not only the actual operating program, but all of the aids used by programmers to produce the program.

Both initial system expense and long-term operating expense are materially reduced when programming is accomplished in a fast and accurate manner. The GE/PAC 4000 software package reduces programming costs by:

- ☐ Facilitating a systematic approach in writing computer programs.
- ☐ Offering flexibility for future changes in user process.
- ☐ Enabling user to be self-sufficient in developing system programs.
- ☐ Providing software designed especially for programming process functions.
- ☐ Converting existing FORTRAN II program to on-line routines.

Complete software packages for the GE/PAC 4000 are grouped in three categories: Program Preparation Aids, Standard On-line Functions and Debugging Aids.

PROGRAM PREPARATION AIDS

- ☐ Facilitate translating process functions into computer instructions.
- ☐ Increase speed and accuracy in preparing programs
- ☐ Aid in documenting and debugging programs
- ☐ Operate locally on GE/PAC 4000, GE 412 or GE 200 series computer systems.

Process Assembler Language (PAL)

- Enables programmer to code programs in systematic and well-documented fashion
- Operates on line as well as off line
- Generates single and double precision constants to a specified scale factor or in floating-point format
- Provides built-in check features which detect and notify programmer of coding errors

FORTRAN Compilers

- Enable powerful algebraic and verbal statements to be written with minimum time and effort
- Operate on line or off line
- Permit experienced FORTRAN programmers to make easy transition to GE/PAC 4000 programming
- Allow previously written FORTRAN II programs to operate on the GE/PAC 4000

Tabular Sequence Control (TASC)

- Simplifies and speeds programming of process control functions which are sequential in nature
- Facilitates subsequent revisions to sequential control programs

STANDARD ON-LINE FUNCTIONS

- ☐ Common routines suitable for numerous applications
- ☐ Require little or no re-work by user programmer
- ☐ Use of pre-checked routines eliminates programming and debugging time

Monitor and Monitor-Compatible Programs

- Schedules and gives priority assignment to system functions
- Enables user to have system running on-line in minimum time
- Provides communication between functions and peripheral equipment

Math Routines

- Include commonly used math functions in fixed or floating point, single or double word length arithmetic
- Available from General Electric library to all GE/PAC 4000 users
- GE/PAC 4000 users receive up-to-date abstracts of new routines as they are developed

DEBUGGING AIDS

- ☐ Facilitate and simplify on-site troubleshooting
- ☐ Help locate trouble quickly, reducing delay

Program Debugging Aids

- Include load-compare, dump, memory change routines
- Load-compare and dump are available in on-line as well as off-line form
- On-line debugging aids are plug-in package to MONITOR system
- Debugging aids proved by on-site experience provide powerful means of keeping program documentation up to date.

Hardware Diagnostic Programs

- Minimize delays by rapidly testing computer hardware and indicating areas where trouble exists
- Cover peripheral devices as well as central processor

GENERAL ELECTRIC
PROCESS COMPUTER SECTION
PHOENIX, ARIZONA

PROCESS LANGUAGE STATEMENT CODING FORM

Project Name
Program Name
Page of Date
Programmer

	LOCATION*	TYPE (OP CODE)	STATEMENT (OPERAND)	BRANCH CONTROL FIELD C	=0	≠0	+	−	Any C
0		LDA	2,3						
1		SUB	LC						
2		TZE							
3		BTS	SR62						
4		LDA	PASS						
5		TEV	0						
6		LDA	K2BIT						
7		BTS	SR63						
0		LDA	LC						
1		STA	2,3						
2		LDA	KMBIT						
3		ØRA	1,3						
4		STA	1,3						
5	SR63	ØRA	ERRØR						
6		STA	ERRØR						

WØRD 3 - ØCTAL EQUIVALENT
LØCATIØN CØUNTER
TØ EXIT
TEST FØR WHICH PASS
SECØND PASS ERRØR
SECØND PASS
FIRST PASS
PLACE NEW ØCTAL EQUIVALENT IN WØRD 3

FIGURE 1

PROGRAM PREPARATION AIDS

Program Preparation Aids enable a programmer to translate a process function into actual computer instructions. Use of a symbolic language greatly increases the speed and accuracy of preparing a program and also aids in the documentation and debugging of the program. To provide the programmer with the most effective means of coding a program, General Electric has developed processing programs for three powerful program preparation languages—Process Assembler Language (PAL), FORTRAN II and Tabular Sequence Control (TASC). These language processors are designed to produce operating programs for systems with varying configurations, from simple paper tape input/output, core memory only to large systems with high performance devices such as punched card equipment, magnetic drum, magnetic disc, high-speed printers and remote peripherals. Additional service to the user has been provided—PAL and FORTRAN processors operate on GE/PAC 4000, GE 412 or GE 200 series computer systems. The GE 200 series language processor versions enable routines to be assembled or compiled at the various General Electric Information Processing Centers throughout the country and overseas.

Process Assembler Language

The Process Assembler Language accepts coded symbolic instructions and translates them into computer instructions. These symbolic instructions are coded by the programmer on a form, Figure 1, from which cards or paper tape are punched when the coding is completed. The cards or paper tapes are then read into the computer on which the PAL assembler is operating.

The output from the assembler is a listing from a printer or typewriter of the object program and a paper tape which is used to load the new program into the computer. The assembler program has built-in check features which detect and notify the programmer of many types of coding errors. The listing provides documentation of the program and is invaluable as a debugging aid.

The on-line PAL assembler accepts the same symbolic language as above and has the ability to assemble programs while the GE/PAC 4000 is handling process data. Its advantage is that it can be used to assemble or re-assemble programs at the user site, so they may be integrated into the system with no interruption to process computing.

As shown in Figure 2, the listing provides the symbolic instructions as coded and also the octal core locations, instructions, and constants of the assembled program. For further aid in debugging, the listing reproduces all comments from the coding sheet. The three columns of numbers in Figure 2 represent:

Core location
Instruction in absolute format (as a debugging aid)
Instruction in relative format (as actually stored in the computer)

The PAL program makes maximum use of the relative addressing feature of the GE/PAC 4000. It assembles the operand value relative to the location of the instruction itself rather than the absolute value. With this feature, it is possible to operate a program from any place in core memory without modification, thereby adding a new dimension of flexibility to system program organization.

In addition to the computer hardware instructions, PAL translator makes maximum use of pseudo instructions for storage assignments, symbol definition, and generation of constants to provide better programmer efficiency. These instructions include block storage reservation, single and multi-word constants, single and double-word floating constants, etc.

```
                                  ***  *
01154  06100100  06176724     SR6   STX SAVE,1
01155  00000110  00076733           LDA LOC          LABEL
01156  31000222  31077044           SUB CONST
01157  05004670  05004670           TZE
01160  34001245  34040065           BTS SR62         EMPTY LOC FLD - TO EXIT
01161  00000157  00076776           LDA TABLE        TOP OF SYMBOL TABLE
01162  31000201  31077017           SUB LDEF         BOTTOM OF OP TABLE
01163  05004727  05004727           TOD 23           TEST FOR NEGATIVE
01164  00000240  00077054           LDA KFBIT
01165  34001223  34040036           BTS SR63         TO ERROR, TABLE OVERLAP
01166  16300200  16377012           LDX SYMX,3       BOTTOM OF SYMBOL TABLE
01167  00300000  00300000     SR64  LDA 0,3          WORD 1 = LABEL
01170  05004670  05004670           TZE              END OF SYMBOLS
01171  34001232  34040041           BTS SR611        YES
01172  31000110  31076716           SUB LOC          NO--1ST 4 CHAR SAME AS THIS
01173  05004770  05004770           TNZ
01174  34001226  34040032           BTS SR61         NO
01175  00300001  00300001           LDA 1,3          YES--WORD 2 = LABEL
01176  32000160  32076762           STA WRD2
01177  20000220  20077021           ANA MSK          CHAR 5-6
01200  31000111  31076711           SUB LOC+1
01201  05004770  05004770           TNZ
01202  34001226  34040024           BTS SR61
01203  00000160  00076755           LDA WRD2
01204  21000101  21076675           ORA ERROR
01205  32000101  32076674           STA ERROR
01206  00300002  00300002           LDA 2,3          WORD 3 = OCTAL EQUIVALENT
01207  31000104  31076675           SUB LC           LOCATION COUNTER
01210  05004670  05004670           TZE
01211  34001245  34040034           BTS SR62         TO EXIT
01212  00000102  00076670           LDA PASS         TEST FOR WHICH PASS
01213  05070700  05070700           TEV 0
01214  00000250  00077034           LDA K2BIT        SECOND PASS ERROR
01215  34001223  34040006           BTS SR63         SECOND PASS
01216  00000104  00076666           LDA LC           FIRST PASS
01217  32300002  32300002           STA 2,3          PLACE NEW OCTAL EQUIVALENT IN WORD 3
01220  00000242  00077022           LDA KMBIT
01221  21300001  21300001           ORA 1,3
01222  32300001  32300001           STA 1,3
01223  21000101  21076656     SR63  ORA ERROR
01224  32000101  32076655           STA ERROR
01225  14001245  14040020           BRU SR62         TO EXIT
01226  26337775  26337775     SR61  INX -3,3          DECREMENT TO NEXT LOCATION
01227  00300002  00300002           LDA 2,3
01230  05004770  05004770           TNZ              TEST FOR EMPTY LOCATION
01231  34001167  34077736           BTS SR64         CHECK NEXT LOCATION
01232  00000110  00076656     SR611 LDA LOC          WORD 1, LABEL
```

FIGURE 2

FORTRAN Compilers

To make the writing of new programs as easy and efficient as possible, General Electric has created FORTRAN compilers for the GE/PAC 4000. These compilers go a step beyond the PAL program in that they enable the programmer to write his program in terms of "statements" which employ familiar language and symbols rather than the symbolic code required by PAL. An example of such a statement might be $Y = A/B + C - SINF(D + E)$

where A, B, C, D, and E are variables which have been defined by the programmer in other statements. A statement such as this, when presented to a FORTRAN compiler, will cause the compiler to automatically generate all the step-by-step machine instructions necessary to perform the calculations called for in the statement. Thus, the programmer is freed from the time consuming details of step-by-step programming and allowed to concentrate more fully on the problem at hand.

In preparing the FORTRAN compilers for the GE/PAC 4000, General Electric has incorporated several special features which facilitate the writing and running of programs in a real-time process control environment.

Compatibility with MONITOR

The FORTRAN compilers have been designed so that the programs they produce will have numerous special provisions for operation within the G-E MONITOR system. Thus, new programs may be easily incorporated into existing MONITOR systems.

Compatibility with Process Assembler Language

The programmer is free to intermix FORTRAN statements with PAL statements within a single program. This allows the programmer to switch back and forth between the two languages arbitrarily, always free to choose the language in which he can proceed most efficiently. Output from the compiler is in the form of PAL symbolic coding.

Bit manipulation capability

Special FORTRAN statements are available to the programmer through which he may exploit the ability of the GE/PAC 4000 to manipulate individual bits within a word. In this manner, individual bits may be treated as separate variables and may be set, reset, and tested.

Bulk storage — core transfers

Transfers of information between drum or disc storage and core storage may be implemented through the FORTRAN compiler by means of special statements provided for this purpose.

Floating-point Operation

Two types of floating-point numbers have been defined for the GE/PAC 4000. FORTRAN compilers are available so that data may be accepted in either single or double-word floating-point form. The program generated by the particular compiler may be made to output data in that form.

Statement Repertory

A large repertory of allowed statements, plus a full complement of library subroutines, makes for ease and flexibility in programming with the FORTRAN compiler.

Besides providing ease and flexibility in writing new programs, the FORTRAN compiler allows the user's previously written FORTRAN II program to be easily adapted to the GE/PAC 4000. After little or no modification to the source program, the user simply processes the source program through the GE/PAC 4000 FORTRAN compiler. The output from the compiler is then processed through the PAL program, yielding a version of the user's program which is ready to run on the GE/PAC 4000.

The FORTRAN compiler, like the PAL program, is available in on-line free-time as well as off-line form for the GE/PAC 4000. Thus, program compilations may be performed on the GE/PAC 4000 at the same time as regular process monitoring and control functions are being executed, without interfering with these functions.

Tabular Sequence Control (TASC)

In cases where it is desired to program a process control function which is sequential in nature (such as process start-up and shut-down under computer control), the time and effort required to program such a function may be reduced by using TASC, a special language offered by General Electric.

TASC permits the programmer to code information in tabular form concerning each control action in the sequence. Examples of this tabular information are: (a) identification of the control action, (b) number of times to try the action, and (c) amount of time to allow for completion of the action. The TASC assembly program operates on this information to produce a program which will control the timing and order of execution of a group of subroutines. With each of these subroutines designed to execute some specific control action, the desired process control sequence is achieved. (Note: The subroutines themselves are not produced by TASC. They must be written separately to meet individual process needs.) In addition to fixed sequences of control actions, TASC is capable of producing programs which will make choices between alternate sequences based on real-time process dynamics. The TASC assembler program operates on the GE 412 to produce GE/PAC 4000 control programs.

STANDARD ON-LINE FUNCTIONS

Standard on-line functions are portions of a total system program that are common from one computer application to another. Because they are used so frequently, optimum execution time and utilization of memory have been stressed in their development. For most applications, the use of these functions require little or no re-work by user programmers. Use of these pre-checked routines eliminates programming and debugging time.

MONITOR

MONITOR provides the skeleton of a real-time program by scheduling and giving priority assignment to system functions. By using MONITOR, the user is capable of having an on-line program running with minimum time spent on the program. A system flowchart illustrating MONITOR is shown in Figure 3.

General Electric offers a choice between several different versions of MONITOR, depending on the system configuration. With MONITOR tailored to the application, the system may then be implemented in building-block fashion with greater confidence and fewer delays.

The routines that make up MONITOR are clear and well-defined, which makes for easy understanding of the system. The layout of the MONITOR package facilitates the addition of system functions by user programmers. The routines that comprise MONITOR are:

- ☐ Time and diagnostic count
- ☐ Executive Control Program
- ☐ Save registers routine
- ☐ Restore registers routine
- ☐ Turn on program
- ☐ Turn off program
- ☐ Set program delay
- ☐ Priority change subroutine

In addition to the above, MONITOR also includes the following two routines for core-bulk storage GE/PAC 4000 computers

- ☐ Drum or disc transfer subroutine
- ☐ Drum or disc transfer driver

Other programs compatible to MONITOR are:

- ☐ Input/output driver
- ☐ Output subroutine
- ☐ Output program, consisting of
  - Peripheral selection
  - Decimal floating-point routine
  - Decimal fixed-point routine
  - Octal conversion routine
  - BCD conversion routine
  - Time conversion routine
- ☐ Input function, which includes
  - Input communication subroutine
  - Input program
- ☐ Multiple and Timed Output function
- ☐ Analog Scan function

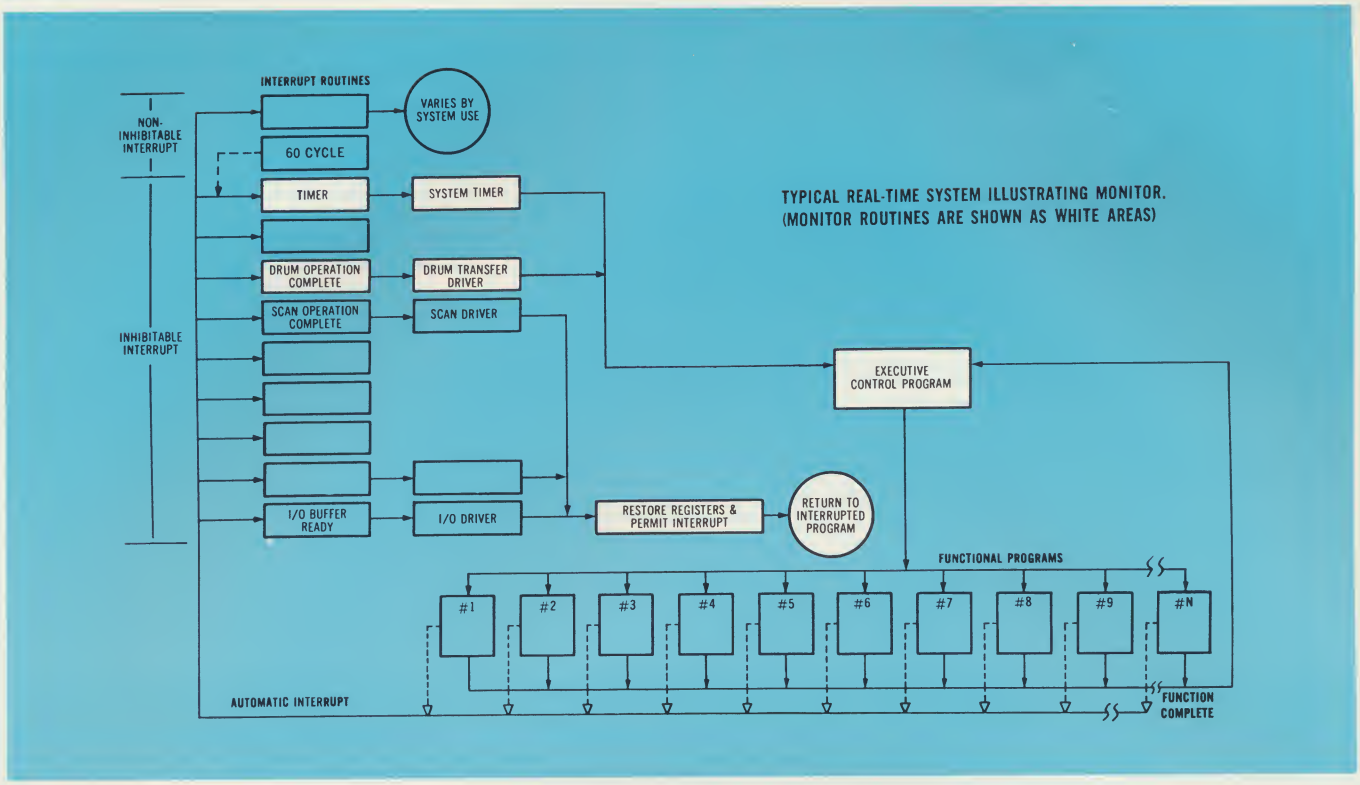


FIGURE 3

The Time and Diagnostic Count routine maintains the value of current time (in seconds or fractions of seconds) which is used by the Executive Control Program in determining execution time of the functional programs.

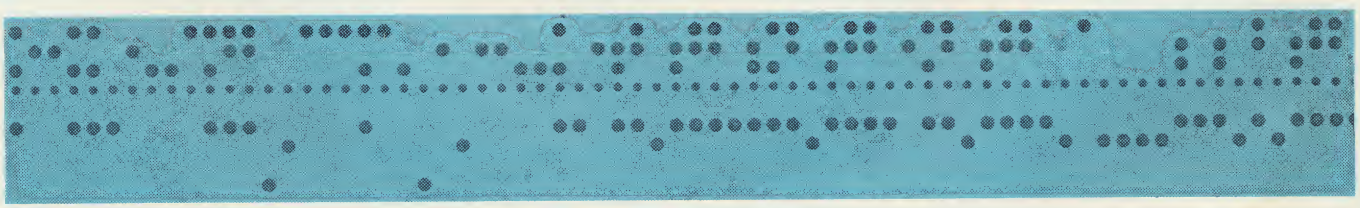
The Executive Control Program (ECP) is the real heart of the MONITOR system as it initiates functional programs according to their scheduled interval and priority. The ECP provides for easy writing and addition of functional programs. The number of functional programs that the ECP can manage is limited only by the computer core, drum or disc size and the length of the individual functions. Most MONITOR systems allow 25 to 50 functional programs. To accomplish on-line requirements as they occur, the GE/PAC 4000 uses automatic priority interrupt, which may interrupt a program at any time.

Two MONITOR routines (Save Registers and Restore Registers) are used in conjunction with system interrupts. These routines record and then reinstate the interrupted program after the priority function has been accomplished.

To further reduce housekeeping chores of functional programs using MONITOR, Turn Program On, Set Program Delay and Turn Program Off routines are supplied. These routines enable a user function to be initiated at a specified interval or to be completely turned off until some exterior influence (such as a demand) reinitiates the function. For GE/PAC 4000 computers equipped with a magnetic drum or disc memory, MONITOR will also provide the transfer linkage for information flowing between core and bulk storage. The user functional program will use the Drum or Disc Transfer subroutine to initiate a transfer of information between core and drum or disc. While the transfer is in progress, MONITOR initiates other functions that require action, thereby permitting full utilization of the central processor. When the transfer is complete, the ECP will reinitiate the functional program that requested the transfer. Completion of a bulk storage — core transfer is detected by automatic priority interrupt which allows the data involved in the transfer to be acted upon as expeditiously as possible.

MONITOR Compatible Functions

MONITOR Compatible Functions are those functions that are developed for specific applications which may be used by other computer users. These routines are



written in a general form so that they require a minimum of re-working to be suitable for other similar applications. Other examples are Analog Scan Request subroutine and driver, corrective action diagnostic, Multiple and Timed Contact Output Request subroutines and drivers.

The Input and Output programs permit user functional programs to communicate with peripheral devices such as typewriters, readers, punches, etc., in an orderly, step-by-step fashion. The Input and Output programs determine whether the peripheral is available for use by the functional program, and read in or put out data.

The Input and Output programs eliminate a large amount of editing and bookkeeping that would be required if they were not available. The Output program converts binary floating-point to decimal fixed-point output, binary fixed-point to decimal fixed-point output, binary to octal output, or binary data to numeric and alphabetic character output, or time counts to decimal hours and minutes.

The Input/Output driver operates the peripherals through automatic priority interrupt.

Math routines

Math routines which are usually used in subroutine form include fixed or floating-point, single or double-precision math functions. These routines are available from the General Electric library to all GE/PAC 4000 computer users. They may be obtained in the form of punched cards or paper tape, along with flowcharts, listings and instructions for their use. Examples of these routines are square root, trigonometric, exponential functions, etc. GE/PAC 4000 users receive up-to-date abstracts of each routine as it is developed.

DEBUGGING AIDS

General Electric offers a group of standard routines specifically designed to aid the programmer or maintenance person in pinpointing trouble within the computer system. On-site experience has proved these debugging aids to be extremely valuable in terms of on-site system implementation. The difficulties posed by the inherent complexity of the computer system may be minimized by use of these routines, and costly delays thereby reduced.

Debugging aids for the GE/PAC 4000 fall into two categories: Program Debugging Aids (for troubleshooting software) and Hardware Diagnostic Programs (for troubleshooting hardware).

Program Debugging Aids

Experience has shown that program debugging aids provide a powerful means of updating program documentation as well as helping the programmer to locate errors in his program. General Electric has developed extremely useful program debugging aids, all of which are available in both on-line and off-line form. The on-line versions use the MONITOR system and are capable of being run at the same time as the main process monitoring and control functions are being executed. This is accomplished by allowing the debugging routines to utilize whatever free time is available in the central processor. Debugging may be accomplished without interrupting normal process monitoring and control functions.

Program loaders provide the means to load programs and data into computer storage through punched-card or paper-tape readers. In addition, a wired-in loader is available for initial program loading. The Compare feature of the loader is available for use by the programmer in cases where he suspects that a part of his program may have accidentally become altered or destroyed in memory. Each location in memory is compared with the corresponding entry on a paper tape of the program in question. If any disagreement exists, the program types out the address of the memory location, the contents of the memory location, and the contents of the corresponding entry on paper tape. The dump program is used to record the contents of computer memory, either through the typewriter or paper-tape punch.

The Memory Change program is used for changing the contents of a core or drum/disc location through computer console switches or an input typewriter. Documentation showing the location, contents before change, and contents after the change are typed out on the console typewriter.

The Memory Change program has the added facility of displaying the location and its contents before the change is executed.

Hardware Diagnostic Programs

General Electric offers a comprehensive package of hardware diagnostic programs for the GE/PAC 4000. These programs have proved highly effective in helping maintenance personnel locate trouble in the computer hardware in a rapid and systematic way.

The use of these routines causes the computer to execute sequences of instructions which are designed to "exercise" specific sub-groups of hardware in worst-case fashion. The manner in which the computer responds to these sequences of instructions may be interpreted by referring to a diagnostics handbook which is furnished with the routines. The trouble-shooter is able to "home in" on the trouble in a direct and logical way. Naturally, these hardware diagnostic programs must be run in off-line fashion.

The hardware diagnostic package for the GE/PAC 4000 includes the following routines:

- ☐ Arithmetic unit diagnostic
- ☐ Core test
- ☐ Drum or disc diagnostic
- ☐ Automatic program interrupt diagnostic
- ☐ Peripheral buffer diagnostic and peripheral test
- ☐ Scanner test

GE/PAC 4000
GENERAL ELECTRIC PROCESS AUTOMATION COMPUTER

SOFTWARE SPECIFICATIONS

Process Assembler Language (PAL)

ASSEMBLING MACHINE: GE 215, GE 225, GE 235, GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Console typewriter
High-speed printer
Magnetic tape units
Card reader
Paper-tape punch

ASSEMBLING MACHINE: GE/PAC 4000

INPUT: Punched cards or paper-tape
MEMORY REQUIREMENT: (off-line) 2K to 4K of core
(on-line) 2K of core plus 6K of drum or disc
(in addition to the process memory requirements)

PERIPHERAL EQUIPMENT: Card or paper-tape reader
Console typewriter or printer
Paper-tape punch

OUTPUT: Magnetic tape
Paper tape or cards and program listing

FORTRAN Compilers

COMPILING MACHINE: GE 215, GE 225, GE 235, GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Card reader
Console Typewriter
Card punch
Paper-tape punch (option)
High speed printer
Magnetic tape unit

OUTPUT: Punched cards, magnetic tape or paper tape and program listing
(output is in PAL format)

COMPILING MACHINE: GE/PAC 4000

INPUT: Paper tape
MEMORY REQUIREMENT: (off-line) 8K of core
(on-line) 4K of core plus 8K of drum or disc
(in addition to the process memory)

PERIPHERAL EQUIPMENT: Paper-tape or card reader
Paper-tape or card punch
Console typewriter
High-speed printer (option)

OUTPUT: Paper tape or cards and/or program listing
(output is in PAL format)

Tabular Sequence Control (TASC)

ASSEMBLING MACHINE: GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Console typewriter
High-speed printer
Magnetic tape unit
Card reader
Paper-tape punch

OUTPUT: Magnetic tape, binary paper tape or cards and program listing

The software described in this brochure consists of programs now available and those planned for the near future. General Electric reserves the right to change and/or delete software projects without notice.

GENERAL ELECTRIC

PROCESS COMPUTER SECTION
INDUSTRY CONTROL DEPARTMENT
PHOENIX, ARIZONA

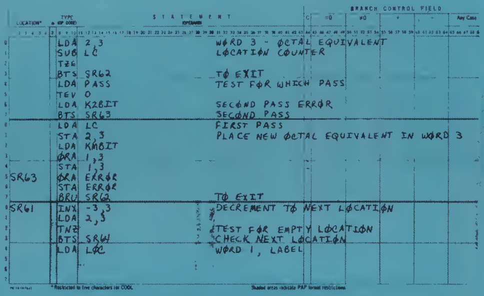
5/65 (5M)

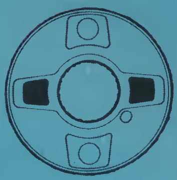
PRINTED IN U.S.A.

$$A_X + B_Y + C_Z = K$$

```
01203   00000160   00076755          LDA  WRD2
01204   21000101   21076675          ORA  ERROR
01205   32000101   32076674          STA  ERROR
01206   00300002   00300002          LDA  2,3
01207   31000104   31076675          SUB  LC
01210   05004670   05004670          TZE
01211   34001245   34040034          BTS  SR62
01212   00000102   00076670          LDA  PASS
01213   05070700   05070700          TEV  0
01214   00000250   00077034          LDA  K2BIT
01215   34001223   34040006          BTS  SR63
01216   00000104   00076066          LDA  LC
01217   32300002   32300002          STA  2,3
01220   00000242   00077022          LDA  KMBIT
01221   21300001   21300001          ORA  1,3
01222   32300001   32300001          STA  1,3
01223   21000101   21076656   SR63   ORA  ERROR
01224   32000101   32076655          STA  ERROR
01225   14001245   14040020          BRU  SR62
01226   26337775   26337775   SR61   INX  -3,3
01227   00300002   00300002          LDA  2,3
01230   05004770   05004770          TNZ
01231   34001167   34077736          BTS  SR64
01232   00000110   00076656   SR611  LDA  LOC
```

$$F(X, Y) = (X + Y)^*(X - Y)$$





SOFTWARE

for the

GE PAC 4000

GENERAL ELECTRIC PROCESS AUTOMATION COMPUTER

GENERAL ELECTRIC

GENERAL ELECTRIC
PROCESS COMPUTER SECTION
PHOENIX, ARIZONA

PROCESS LANGUAGE STATEMENT CODING FORM

Project Name
Program Name
Page of Date
Programmer

	LOCATION*	TYPE (OP CODE)	STATEMENT (OPERAND)		BRANCH CONTROL FIELD C	=0	≠0	+	−	Any C
0		LDA	2,3	WØRD 3 - ØCTAL EQUIVALENT						
1		SUB	LC	LØCATIØN CØUNTER						
2		TZE								
3		BTS	SR62	TØ EXIT						
4		LDA	PASS	TEST FØR WHICH PASS						
5		TEV	0							
6		LDA	K2BIT	SECØND PASS ERRØR						
7		BTS	SR63	SECØND PASS						
0		LDA	LC	FIRST PASS						
1		STA	2,3	PLACE NEW ØCTAL EQUIVALENT IN WØRD 3						
2		LDA	KMBIT							
3		ØRA	1,3							
4		STA	1,3							
5	SR63	ØRA	ERRØR							
6		STA	ERRØR							

FIGURE 1

PROGRAM PREPARATION AIDS

Program Preparation Aids enable a programmer to translate a process function into actual computer instructions. Use of a symbolic language greatly increases the speed and accuracy of preparing a program and also aids in the documentation and debugging of the program. To provide the programmer with the most effective means of coding a program, General Electric has developed processing programs for three powerful program preparation languages—Process Assembler Language (PAL), FORTRAN II and Tabular Sequence Control (TASC). These language processors are designed to produce operating programs for systems with varying configurations, from simple paper tape input/output, core memory only to large systems with high performance devices such as punched card equipment, magnetic drum, magnetic disc, high-speed printers and remote peripherals. Additional service to the user has been provided—PAL and FORTRAN processors operate on GE/PAC 4000, GE 412 or GE 200 series computer systems. The GE 200 series language processor versions enable routines to be assembled or compiled at the various General Electric Information Processing Centers throughout the country and overseas.

Process Assembler Language

The Process Assembler Language accepts coded symbolic instructions and translates them into computer instructions. These symbolic instructions are coded by the programmer on a form, Figure 1, from which cards or paper tape are punched when the coding is completed. The cards or paper tapes are then read into the computer on which the PAL assembler is operating.

The output from the assembler is a listing from a printer or typewriter of the object program and a paper tape which is used to load the new program into the computer. The assembler program has built-in check features which detect and notify the programmer of many types of coding errors. The listing provides documentation of the program and is invaluable as a debugging aid.

The on-line PAL assembler accepts the same symbolic language as above and has the ability to assemble programs while the GE/PAC 4000 is handling process data. Its advantage is that it can be used to assemble or re-assemble programs at the user site, so they may be integrated into the system with no interruption to process computing.

As shown in Figure 2, the listing provides the symbolic instructions as coded and also the octal core locations, instructions, and constants of the assembled program. For further aid in debugging, the listing reproduces all comments from the coding sheet. The three columns of numbers in Figure 2 represent:

Core location
Instruction in absolute format (as a debugging aid)
Instruction in relative format (as actually stored in the computer)

The PAL program makes maximum use of the relative addressing feature of the GE/PAC 4000. It assembles the operand value relative to the location of the instruction itself rather than the absolute value. With this feature, it is possible to operate a program from any place in core memory without modification, thereby adding a new dimension of flexibility to system program organization.

In addition to the computer hardware instructions, PAL translator makes maximum use of pseudo instructions for storage assignments, symbol definition, and generation of constants to provide better programmer efficiency. These instructions include block storage reservation, single and multi-word constants, single and double-word floating constants, etc.

```
                                  ***  *
01154  06100100  06176724     SR6    STX SAVE,1
01155  00000110  00076733            LDA LOC          LABEL
01156  31000222  31077044            SUB CONST
01157  05004670  05004670            TZE
01160  34001245  34040065            BTS SR62         EMPTY LOC FLD - TO EXIT
01161  00000157  00076776            LDA TABLE        TOP OF SYMBOL TABLE
01162  31000201  31077017            SUB LDEF         BOTTOM OF OP TABLE
01163  05004727  05004727            TOD 23           TEST FOR NEGATIVE
01164  00000240  00077054            LDA KFBIT
01165  34001223  34040036            BTS SR63         TO ERROR, TABLE OVERLAP
01166  16300200  16377012            LDX SYMX,3       BOTTOM OF SYMBOL TABLE
01167  00300000  00300000     SR64   LDA 0,3          WORD 1 - LABEL
01170  05004670  05004670            TZE              END OF SYMBOLS
01171  34001232  34040041            BTS SR611        YES
01172  31000110  31076716            SUB LOC          NO--1ST 4 CHAR SAME AS THIS
01173  05004770  05004770            TNZ
01174  34001226  34040032            BTS SR61         NO
01175  00300001  00300001            LDA 1,3          YES--WORD 2 - LABEL
01176  32000160  32076762            STA WRD2
01177  20000220  20077021            ANA MSK          CHAR 5-6
01200  31000111  31076711            SUB LOC+1
01201  05004770  05004770            TNZ
01202  34001226  34040024            BTS SR61
01203  00000160  00076755            LDA WRD2
01204  21000101  21076675            ORA ERROR
01205  32000101  32076674            STA ERROR
01206  00300002  00300002            LDA 2,3          WORD 3 - OCTAL EQUIVALENT
01207  31000104  31076675            SUB LC           LOCATION COUNTER
01210  05004670  05004670            TZE
01211  34001245  34040034            BTS SR62         TO EXIT
01212  00000102  00076670            LDA PASS         TEST FOR WHICH PASS
01213  05070700  05070700            TEV 0
01214  00000250  00077034            LDA K2BIT        SECOND PASS ERROR
01215  34001223  34040006            BTS SR63         SECOND PASS
01216  00000104  00076666            LDA LC           FIRST PASS
01217  32300002  32300002            STA 2,3          PLACE NEW OCTAL EQUIVALENT IN WORD 3
01220  00000242  00077022            LDA KMBIT
01221  21300001  21300001            ORA 1,3
01222  32300001  32300001            STA 1,3
01223  21000101  21076656     SR63   ORA ERROR
01224  32000101  32076655            STA ERROR
01225  14001245  14040020            BRU SR62         TO EXIT
01226  26337775  26337775     SR61   INX -3,3         DECREMENT TO NEXT LOCATION
01227  00300002  00300002            LDA 2,3
01230  05004770  05004770            TNZ              TEST FOR EMPTY LOCATION
01231  34001167  34077736            BTS SR64         CHECK NEXT LOCATION
01232  00000110  00076656     SR611  LDA LOC          WORD 1, LABEL
```

FIGURE 2

FORTRAN Compilers

To make the writing of new programs as easy and efficient as possible, General Electric has created FORTRAN compilers for the GE/PAC 4000. These compilers go a step beyond the PAL program in that they enable the programmer to write his program in terms of "statements" which employ familiar language and symbols rather than the symbolic code required by PAL. An example of such a statement might be

$$Y = A/B + C - SINF(D + E)$$

where A, B, C, D, and E are variables which have been defined by the programmer in other statements. A statement such as this, when presented to a FORTRAN compiler, will cause the compiler to automatically generate all the step-by-step machine instructions necessary to perform the calculations called for in the statement. Thus, the programmer is freed from the time consuming details of step-by-step programming and allowed to concentrate more fully on the problem at hand.

In preparing the FORTRAN compilers for the GE/PAC 4000, General Electric has incorporated several special features which facilitate the writing and running of programs in a real-time process control environment.

Compatibility with MONITOR

The FORTRAN compilers have been designed so that the programs they produce will have numerous special provisions for operation within the G-E MONITOR system. Thus, new programs may be easily incorporated into existing MONITOR systems.

Compatibility with Process Assembler Language

The programmer is free to intermix FORTRAN statements with PAL statements within a single program. This allows the programmer to switch back and forth between the two languages arbitrarily, always free to choose the language in which he can proceed most efficiently. Output from the compiler is in the form of PAL symbolic coding.

Bit manipulation capability

Special FORTRAN statements are available to the programmer through which he may exploit the ability of the GE/PAC 4000 to manipulate individual bits within a word. In this manner, individual bits may be treated as separate variables and may be set, reset, and tested.

Bulk storage — core transfers

Transfers of information between drum or disc storage and core storage may be implemented through the FORTRAN compiler by means of special statements provided for this purpose.

Floating-point Operation

Two types of floating-point numbers have been defined for the GE/PAC 4000. FORTRAN compilers are available so that data may be accepted in either single or double-word floating-point form. The program generated by the particular compiler may be made to output data in that form.

Statement Repertory

A large repertory of allowed statements, plus a full complement of library subroutines, makes for ease and flexibility in programming with the FORTRAN compiler.

Besides providing ease and flexibility in writing new programs, the FORTRAN compiler allows the user's previously written FORTRAN II program to be easily adapted to the GE/PAC 4000. After little or no modification to the source program, the user simply processes the source program through the GE/PAC 4000 FORTRAN compiler. The output from the compiler is then processed through the PAL program, yielding a version of the user's program which is ready to run on the GE/PAC 4000.

The FORTRAN compiler, like the PAL program, is available in on-line free-time as well as off-line form for the GE/PAC 4000. Thus, program compilations may be performed on the GE/PAC 4000 at the same time as regular process monitoring and control functions are being executed, without interfering with these functions.

Tabular Sequence Control (TASC)

In cases where it is desired to program a process control function which is sequential in nature (such as process start-up and shut-down under computer control), the time and effort required to program such a function may be reduced by using TASC, a special language offered by General Electric.

TASC permits the programmer to code information in tabular form concerning each control action in the sequence. Examples of this tabular information are: (a) identification of the control action, (b) number of times to try the action, and (c) amount of time to allow for completion of the action. The TASC assembly program operates on this information to produce a program which will control the timing and order of execution of a group of subroutines. With each of these subroutines designed to execute some specific control action, the desired process control sequence is achieved. (Note: The subroutines themselves are not produced by TASC. They must be written separately to meet individual process needs.) In addition to fixed sequences of control actions, TASC is capable of producing programs which will make choices between alternate sequences based on real-time process dynamics. The TASC assembler program operates on the GE 412 to produce GE/PAC 4000 control programs.

STANDARD ON-LINE FUNCTIONS

Standard on-line functions are portions of a total system program that are common from one computer application to another. Because they are used so frequently, optimum execution time and utilization of memory have been stressed in their development. For most applications, the use of these functions require little or no re-work by user programmers. Use of these pre-checked routines eliminates programming and debugging time.

MONITOR

MONITOR provides the skeleton of a real-time program by scheduling and giving priority assignment to system functions. By using MONITOR, the user is capable of having an on-line program running with minimum time spent on the program. A system flowchart illustrating MONITOR is shown in Figure 3.

General Electric offers a choice between several different versions of MONITOR, depending on the system configuration. With MONITOR tailored to the application, the system may then be implemented in building-block fashion with greater confidence and fewer delays.

The routines that make up MONITOR are clear and well-defined, which makes for easy understanding of the system. The layout of the MONITOR package facilitates the addition of system functions by user programmers. The routines that comprise MONITOR are:

- ☐ Time and diagnostic count
- ☐ Executive Control Program
- ☐ Save registers routine
- ☐ Restore registers routine
- ☐ Turn on program
- ☐ Turn off program
- ☐ Set program delay
- ☐ Priority change subroutine

In addition to the above, MONITOR also includes the following two routines for core-bulk storage GE/PAC 4000 computers

- ☐ Drum or disc transfer subroutine
- ☐ Drum or disc transfer driver

Other programs compatible to MONITOR are:

- ☐ Input/output driver
- ☐ Output subroutine
- ☐ Output program, consisting of
  - Peripheral selection
  - Decimal floating-point routine
  - Decimal fixed-point routine
  - Octal conversion routine
  - BCD-conversion routine
  - Time conversion routine
- ☐ Input function, which includes
  - Input communication subroutine
  - Input program
- ☐ Multiple and Timed Output function
- ☐ Analog Scan function

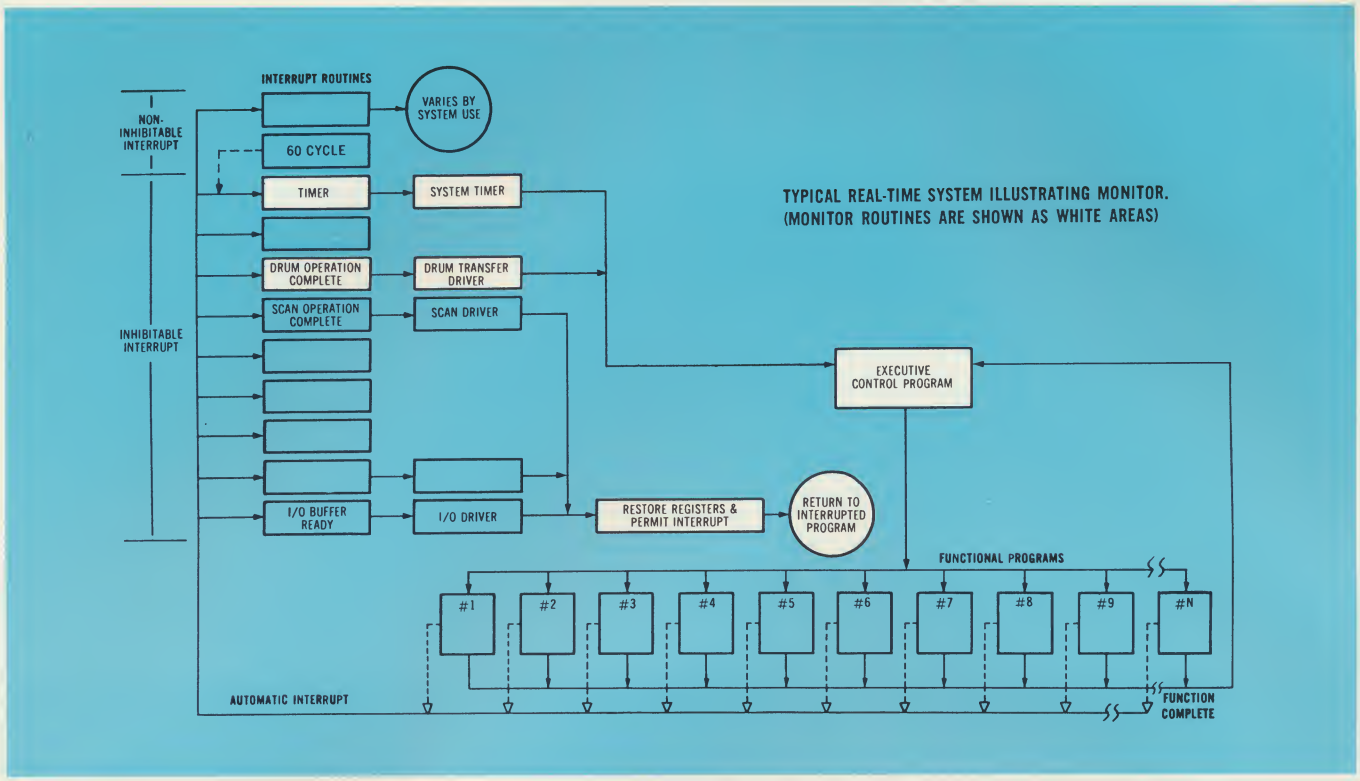


FIGURE 3

The Time and Diagnostic Count routine maintains the value of current time (in seconds or fractions of seconds) which is used by the Executive Control Program in determining execution time of the functional programs.

The Executive Control Program (ECP) is the real heart of the MONITOR system as it initiates functional programs according to their scheduled interval and priority. The ECP provides for easy writing and addition of functional programs. The number of functional programs that the ECP can manage is limited only by the computer core, drum or disc size and the length of the individual functions. Most MONITOR systems allow 25 to 50 functional programs. To accomplish on-line requirements as they occur, the GE/PAC 4000 uses automatic priority interrupt, which may interrupt a program at any time.

Two MONITOR routines (Save Registers and Restore Registers) are used in conjunction with system interrupts. These routines record and then reinstate the interrupted program after the priority function has been accomplished.

To further reduce housekeeping chores of functional programs using MONITOR, Turn Program On, Set Program Delay and Turn Program Off routines are supplied. These routines enable a user function to be initiated at a specified interval or to be completely turned off until some exterior influence (such as a demand) reinitiates the function. For GE/PAC 4000 computers equipped with a magnetic drum or disc memory, MONITOR will also provide the transfer linkage for information flowing between core and bulk storage. The user functional program will use the Drum or Disc Transfer subroutine to initiate a transfer of information between core and drum or disc. While the transfer is in progress, MONITOR initiates other functions that require action, thereby permitting full utilization of the central processor. When the transfer is complete, the ECP will reinitiate the functional program that requested the transfer. Completion of a bulk storage — core transfer is detected by automatic priority interrupt which allows the data involved in the transfer to be acted upon as expeditiously as possible.

MONITOR Compatible Functions

MONITOR Compatible Functions are those functions that are developed for specific applications which may be used by other computer users. These routines are

written in a general form so that they require a minimum of re-working to be suitable for other similar applications. Other examples are Analog Scan Request subroutine and driver, corrective action diagnostic, Multiple and Timed Contact Output Request subroutines and drivers.

The Input and Output programs permit user functional programs to communicate with peripheral devices such as typewriters, readers, punches, etc., in an orderly, step-by-step fashion. The Input and Output programs determine whether the peripheral is available for use by the functional program, and read in or put out data.

The Input and Output programs eliminate a large amount of editing and bookkeeping that would be required if they were not available. The Output program converts binary floating-point to decimal fixed-point output, binary fixed-point to decimal fixed-point output, binary to octal output, or binary data to numeric and alphabetic character output, or time counts to decimal hours and minutes.

The Input/Output driver operates the peripherals through automatic priority interrupt.

Math routines

Math routines which are usually used in subroutine form include fixed or floating-point, single or double-precision math functions. These routines are available from the General Electric library to all GE/PAC 4000 computer users. They may be obtained in the form of punched cards or paper tape, along with flowcharts, listings and instructions for their use. Examples of these routines are square root, trigonometric, exponential functions, etc. GE/PAC 4000 users receive up-to-date abstracts of each routine as it is developed.

DEBUGGING AIDS

General Electric offers a group of standard routines specifically designed to aid the programmer or maintenance person in pinpointing trouble within the computer system. On-site experience has proved these debugging aids to be extremely valuable in terms of on-site system implementation. The difficulties posed by the inherent complexity of the computer system may be minimized by use of these routines, and costly delays thereby reduced.

Debugging aids for the GE/PAC 4000 fall into two categories: Program Debugging Aids (for troubleshooting software) and Hardware Diagnostic Programs (for troubleshooting hardware).

Program Debugging Aids

Experience has shown that program debugging aids provide a powerful means of updating program documentation as well as helping the programmer to locate errors in his program. General Electric has developed extremely useful program debugging aids, all of which are available in both on-line and off-line form. The on-line versions use the MONITOR system and are capable of being run at the same time as the main process monitoring and control functions are being executed. This is accomplished by allowing the debugging routines to utilize whatever free time is available in the central processor. Debugging may be accomplished without interrupting normal process monitoring and control functions.

Program loaders provide the means to load programs and data into computer storage through punched-card or paper-tape readers. In addition, a wired-in loader is available for initial program loading. The Compare feature of the loader is available for use by the programmer in cases where he suspects that a part of his program may have accidentally become altered or destroyed in memory. Each location in memory is compared with the corresponding entry on a paper tape of the program in question. If any disagreement exists, the program types out the address of the memory location, the contents of the memory location, and the contents of the corresponding entry on paper tape. The dump program is used to record the contents of computer memory, either through the typewriter or paper-tape punch.

The Memory Change program is used for changing the contents of a core or drum/disc location through computer console switches or an input typewriter. Documentation showing the location, contents before change, and contents after the change are typed out on the console typewriter.

The Memory Change program has the added facility of displaying the location and its contents before the change is executed.

Hardware Diagnostic Programs

General Electric offers a comprehensive package of hardware diagnostic programs for the GE/PAC 4000. These programs have proved highly effective in helping maintenance personnel locate trouble in the computer hardware in a rapid and systematic way.

The use of these routines causes the computer to execute sequences of instructions which are designed to "exercise" specific sub-groups of hardware in worst-case fashion. The manner in which the computer responds to these sequences of instructions may be interpreted by referring to a diagnostics handbook which is furnished with the routines. The troubleshooter is able to "home in" on the trouble in a direct and logical way. Naturally, these hardware diagnostic programs must be run in off-line fashion.

The hardware diagnostic package for the GE/PAC 4000 includes the following routines:

- ☐ Arithmetic unit diagnostic
- ☐ Core test
- ☐ Drum or disc diagnostic
- ☐ Automatic program interrupt diagnostic
- ☐ Peripheral buffer diagnostic and peripheral test
- ☐ Scanner test

GE/PAC 4000

GENERAL ELECTRIC PROCESS AUTOMATION COMPUTER

SOFTWARE SPECIFICATIONS

Process Assembler Language (PAL)

ASSEMBLING MACHINE: GE 215, GE 225, GE 235, GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Console typewriter
High-speed printer
Magnetic tape units
Card reader
Paper-tape punch

ASSEMBLING MACHINE: GE/PAC 4000

INPUT: Punched cards or paper-tape
MEMORY REQUIREMENT: (off-line) 2K to 4K of core
(on-line) 2K of core plus 6K of drum or disc
(in addition to the process memory requirements)

PERIPHERAL EQUIPMENT: Card or paper-tape reader
Console typewriter or printer
Paper-tape punch

OUTPUT: Magnetic tape
Paper tape or cards and program listing

FORTRAN Compilers

COMPILING MACHINE: GE 215, GE 225, GE 235, GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Card reader
Console Typewriter
Card punch
Paper-tape punch (option)
High speed printer
Magnetic tape unit

OUTPUT: Punched cards, magnetic tape or paper tape and program listing
(output is in PAL format)

COMPILING MACHINE: GE/PAC 4000

INPUT: Paper tape
MEMORY REQUIREMENT: (off-line) 8K of core
(on-line) 4K of core plus 8K of drum or disc
(in addition to the process memory)

PERIPHERAL EQUIPMENT: Paper-tape or card reader
Paper-tape or card punch
Console typewriter
High-speed printer (option)

OUTPUT: Paper tape or cards and/or program listing
(output is in PAL format)

Tabular Sequence Control (TASC)

ASSEMBLING MACHINE: GE 412

INPUT: Punched cards or magnetic tape
MEMORY REQUIREMENT: 8K of core
PERIPHERAL EQUIPMENT: Console typewriter
High-speed printer
Magnetic tape unit
Card reader
Paper-tape punch

OUTPUT: Magnetic tape, binary paper tape or cards and program listing

The software described in this brochure consists of programs now available and those planned for the near future. General Electric reserves the right to change and/or delete software projects without notice.

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